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(54) **LITHIUM SILICATE GLASS CERAMIC AND LITHIUM SILICATE GLASS COMPRISING A MONOVALENT METAL OXIDE**

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See application file for complete search history.

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(57) **ABSTRACT**

Lithium silicate glass ceramics and glasses comprising specific oxides of monovalent elements are described which crystallize at low temperatures and are suitable in particular as dental materials.

26 Claims, No Drawings

LITHIUM SILICATE GLASS CERAMIC AND LITHIUM SILICATE GLASS COMPRISING A MONOVALENT METAL OXIDE

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a National Stage of International patent application PCT/EP2012/070219, filed on Oct. 11, 2012, which claims priority to European patent application No. 11185334.7 filed on Oct. 14, 2011, the disclosures of which are incorporated herein by reference in their entirety.

The invention relates to lithium silicate glass ceramic and glass which contain monovalent metal oxide selected from Rb_2O, Cs_2O and mixtures thereof and are particularly suitable for use in dentistry, preferably for the preparation of dental restorations.

Lithium silicate glass ceramics are characterized as a rule by very good mechanical properties, which is why they have been used for a long time in the dental field and there primarily for the preparation of dental crowns and small bridges. The known lithium silicate glass ceramics usually contain as main components SiO_2, Li_2O, Al_2O_3, Na_2O or K_2O, and nucleating agents such as P_2O_5.

DE 24 51 121 describes lithium disilicate glass ceramics which contain K_2O and Al_2O_3. They are prepared from corresponding nuclei-containing starting glasses which are heated to temperatures of from 850 to 870° C. for the crystallization of lithium disilicate.

EP 827 941 describes sinterable lithium disilicate glass ceramics for dental purposes, which also contain K_2O or Na_2O in addition to La_2O_3. The lithium disilicate crystal phase is produced at a temperature of 850° C.

Lithium disilicate glass ceramics which contain K_2O and Al_2O_3 are known from EP 916 625. A heat treatment is carried out at 870° C. for the formation of lithium disilicate.

EP 1 505 041 describes lithium silicate glass ceramics containing K_2O and Al_2O_3, which, when lithium metasilicate is present as main crystal phase, can be very satisfactorily machined e.g. by means of CAD/CAM processes, in order to then be converted by further heat treatment at temperatures of from 830 to 850° C. into high-strength lithium disilicate glass ceramics.

EP 1 688 398 describes similar K_2O- and Al_2O_3-containing lithium silicate glass ceramics which are moreover substantially free from ZnO. A heat treatment at 830 to 880° C. is applied to them to produce lithium disilicate.

U.S. Pat. No. 5,507,981 describes processes for producing dental restorations and glass ceramics that can be used in these processes. These are in particular lithium disilicate glass ceramics which contain Al_2O_3 and as a rule either Na_2O or K_2O.

U.S. Pat. No. 6,455,451 relates to lithium disilicate glass ceramics which can apparently also contain Cs_2O in specific embodiments. However, in these embodiments the presence of significant amounts of Al_2O_3 and BaO is also necessary. The production of the desired lithium disilicate crystal phase requires high temperatures of from 800 to 1000° C.

WO 2008/106958 discloses lithium disilicate glass ceramics for veneering zirconium oxide ceramics. The glass ceramics contain Na_2O and are produced by heat treatment of nuclei-containing glasses at 800 to 940° C.

WO 2009/126317 describes GeO_2-containing lithium metasilicate glass ceramics which also contain K_2O and Al_2O_3. The glass ceramics are processed to form dental products primarily using machining.

WO 2011/076422 relates to lithium disilicate glass ceramics which also contain K_2O and Al_2O_3 in addition to high levels of ZrO_2 or HfO_2. The crystallization of lithium disilicate takes place at temperatures of from 800 to 1040° C.

Common to the known lithium disilicate glass ceramics is that they require heat treatments at more than 800° C. in order to effect the precipitation of lithium disilicate as main crystal phase. A large quantity of energy is therefore also necessary for their preparation. Further, with the known glass ceramics the alkali metal oxides K_2O or Na_2O, as well as Al_2O_3 and BaO, are as a rule present as essential components which are apparently required for the production of the glass ceramics and in particular the formation of the sought lithium disilicate main crystal phase.

There is therefore a need for lithium silicate glass ceramics during the preparation of which the crystallization of lithium disilicate can be effected at lower temperatures. Further, they should also be able to be prepared without the alkali metal oxides K_2O or Na_2O as well as Al_2O_3 and BaO, previously regarded as necessary, and be suitable in particular for the preparation of dental restorations primarily in view of their optical and mechanical properties.

This object is achieved by the lithium silicate glass ceramic according to any one of claims **1** to **15** or **18**. Also a subject of the invention are the starting glass according to claim **16** or **18**, the lithium silicate glass with nuclei according to claims **17** and **18**, the process for the preparation of the glass ceramic and the lithium silicate glass with nuclei according to claims **19** and **20** as well as the use according to claims **21** and **22**.

The lithium silicate glass ceramic according to the invention is characterized in that it comprises monovalent metal oxide selected from Rb_2O, Cs_2O and mixtures thereof.

It is preferred that the glass ceramic comprises the monovalent metal oxide or mixtures thereof in an amount of from 0.1 to 17.0, in particular 1.0 to 15.0 and particularly preferably 1.5 to 8.0 wt.-%.

It is particularly surprising that the formation of the glass ceramic according to the invention with lithium disilicate as main crystal phase is also achieved in the absence of various components regarded as necessary for conventional glass ceramics, such as in particular K_2O, Na_2O as well as Al_2O_3 and BaO, even at very low and thus advantageous crystallization temperatures of about 700° C.

The glass ceramic according to the invention accordingly preferably comprises less than 1.0, in particular less than 0.5 wt.-%, preferably less than 0.1 wt.-% K_2O. It is particularly preferred substantially free from K_2O.

A glass ceramic is also preferred which comprises K_2O, Na_2O and mixtures thereof in an amount of less than 1.0, in particular less than 0.5 and preferably less than 0.1 wt.-% and particularly preferred is substantially free from K_2O and Na_2O.

Further, a glass ceramic is preferred which comprises less than 5.3, in particular less than 5.1, preferably less than 4.0 and particularly preferred less than 3.0 wt.-% Al_2O_2.

In a further preferred embodiment, the glass ceramic is substantially free from Al_2O_2.

In another preferred embodiment the molar ratio of monovalent metal oxide to Al_2O_2 is at least 0.5 and in particular 0.5 to 1.5.

In a further preferred embodiment, the glass ceramic comprises less than 3.8, in particular less than 3.6 and preferably less than 2.5 wt.-% BaO. It is particularly preferably substantially free from BaO.

A glass ceramic, excluding lithium silicate glass ceramic which comprises at least 6.1 wt.-% ZrO_2, is also preferred.

Further, a glass ceramic, excluding lithium silicate glass ceramic which comprises at least 8.5 wt.-% transition metal oxide selected from the group consisting of oxides of yttrium, oxides of transition metals with an atomic number from 41 to 79 and mixtures of these oxides, is also preferred.

The glass ceramic according to the invention preferably comprises 55.0 to 85.0, in particular 60.0 to 78.0 and preferably 62.0 to 77.0 wt.-% SiO_2.

It is also preferred that the glass ceramic comprises 9.0 to 20.0, in particular 9.0 to 17.0 and particularly preferred 12.0 to 16.0 wt.-% Li_2O.

It is further preferred that the molar ratio between SiO_2 and Li_2O is from 2.2 to 2.6, in particular 2.3 to 2.5 and particularly preferred about 2.4.

The glass ceramic according to the invention can also comprise a nucleating agent. A nucleating agent is preferably present. P_2O_5 is particularly preferably used for this. The glass ceramic preferably comprises 0 to 12.0, in particular 1.0 to 12.0, preferably 2.0 to 9.0 and particularly preferred 2.5 to 7.5 wt.-% P_2O_5.

In a further preferred embodiment, the glass ceramic comprises at least one and preferably all of the following components:

Component	wt.-%
SiO_2	55.0 to 85.0
Li_2O	9.0 to 17.0
Rb_2O and/or Cs_2O	0.1 to 15.0
P_2O_5	0 to 12.0, preferably 1.0 to 12.0.

The glass ceramic according to the invention can moreover also comprise additional components which are selected in particular from oxides of divalent elements, oxides of trivalent elements, further oxides of tetravalent elements, further oxides of pentavalent elements, oxides of hexavalent elements, melt accelerators, colourants and fluorescent agents.

In particular the alkaline earth metal oxides, preferably CaO, BaO, MgO, SrO or a mixture thereof and more preferably MgO come into consideration as oxides of divalent elements.

Suitable oxides of trivalent elements are in particular Y_2O_3. La_2O_3, Bi_2O_3 and mixtures thereof, and preferably Y_2O_3.

The term "further oxides of tetravalent elements" refers to oxides of tetravalent elements with the exception of SiO_2.

Examples of suitable further oxides of tetravalent elements are TiO_2, SnO_2 and GeO_2.

The term "further oxides of pentavalent elements" refers to oxides of pentavalent elements with the exception of P_2O_5.

Examples of suitable further oxides of pentavalent elements are Ta_2O_5 or Nb_2O_5.

Examples of suitable oxides of hexavalent elements are WO_3 and MoO_3.

A glass ceramic which comprises at least one oxide of divalent elements, at least one oxide of trivalent elements, at least one further oxide of tetravalent elements, at least one further oxide of pentavalent elements and/or at least one oxide of hexavalent elements is preferred.

Examples of melt accelerators are fluorides.

Examples of colourants and fluorescent agents are oxides of d- and f-elements, such as the oxides of Ti, V, Sc, Mn, Fe, Co, Ta, W, Ce, Pr, Nd, Tb, Er, Dy, Gd, Eu and Yb. Metal colloids, e.g. of Ag, Au and Pd, can also be used as colourants and in addition can also act as nucleating agents. These metal colloids can be formed e.g. by reduction of corresponding oxides, chlorides or nitrates during the melting and crystallization processes. The metal colloids are preferably present in the glass ceramic in an amount of from 0.005 to 0.5 wt.-%.

In particular, the glass ceramic according to the invention comprises Ag_2O in an amount of from 0.005 to 0.5 wt.-%.

The term "main crystal phase" used below refers to the crystal phase which has the highest proportion by volume compared with other crystal phases.

In one embodiment the glass ceramic according to the invention has lithium metasilicate as main crystal phase. In particular the glass ceramic comprises more than 5 vol.-%, preferably more than 10 vol.-% and particularly preferred more than 15 vol.-% lithium metasilicate crystals, relative to the total glass ceramic.

In a further particularly preferred embodiment, the glass ceramic has lithium disilicate as main crystal phase. In particular the glass ceramic comprises more than 10 vol.-%, preferably more than 20 vol.-% and particularly preferred more than 30 vol.-% lithium disilicate crystals, relative to the total glass ceramic.

The lithium disilicate glass ceramic according to the invention is characterized by particularly good mechanical properties and can be produced e.g. by heat treatment of the lithium metasilicate glass ceramic according to the invention. However, it can in particular be formed by heat treatment of a corresponding starting glass or of a corresponding lithium silicate glass with nuclei.

It has surprisingly been shown that the lithium disilicate glass ceramic according to the invention has very good mechanical and optical properties even in the absence of components regarded as essential for conventional glass ceramics. The combination of its properties even allows it to be used as dental material and in particular material for the preparation of dental restorations.

The lithium disilicate glass ceramic according to the invention has in particular a fracture toughness, measured as K_{IC} value, of at least about 2.0 $MPa \cdot m^{0.5}$ and in particular at least about 2.3 $MPa \cdot m^{0.5}$. This value was determined using the Vickers method and calculated using Niihara's equation.

Further, it has a high biaxial breaking strength of preferably from 400 to 700 MPa. Moreover, it displays a high chemical stability ascertained by mass loss after storage in acetic acid. The chemical stability is in particular less than 100 $\mu g/cm^2$. The biaxial breaking strength and the chemical stability were determined according to ISO 6872 (2008).

The invention also relates to a lithium silicate glass with nuclei that are suitable for forming lithium metasilicate and/or lithium disilicate crystals, wherein the glass comprises the components of the above-described glass ceramics according to the invention. Thus this glass comprises monovalent metal oxide selected from Rb_2O, Cs_2O and mixtures thereof. Reference is made in respect of preferred embodiments of this glass to the preferred embodiments described above of the glass ceramics according to the invention.

The glass with nuclei according to the invention can be produced by heat treatment of a correspondingly composed starting glass according to the invention. The lithium metasilicate glass ceramic according to the invention can then be formed by a further heat treatment, and in turn be converted into the lithium disilicate glass ceramic according to the invention by further heat treatment, or the lithium disilicate glass ceramic according to the invention can also preferably be formed directly from the glass with nuclei. The starting glass, the glass with nuclei and the lithium metasilicate glass ceramic can consequently be regarded as precursors for the production of the high-strength lithium disilicate glass ceramic.

The glass ceramics according to the invention and the glasses according to the invention are present in particular in the form of powders, granular material or blanks, e.g. monolithic blanks, such as platelets, cuboids or cylinders, or powder green compacts, in unsintered, partly sintered or densely-sintered form. They can easily be further processed in these forms. They can, however, also be present in the form of dental restorations, such as inlays, onlays, crowns, veneers, facets or abutments.

The invention also relates to a process for the preparation of the glass ceramic according to the invention and the glass with nuclei according to the invention, in which a correspondingly composed starting glass, the glass with nuclei according to the invention or the lithium metasilicate glass ceramic according to the invention is subjected to at least one heat treatment in the range of from 450 to 950° C., in particular 450 to 800 and preferably 450 to 750° C.

The starting glass according to the invention therefore comprises monovalent metal oxide selected from Rb_2O, Cs_2O and mixtures thereof. In addition, it preferably also comprises suitable amounts of SiO_2 and Li_2O, in order to allows the formation of a lithium silicate glass ceramic, and in particular a lithium disilicate glass ceramic. Moreover, the starting glass can also comprise still further components, such as are given above for the lithium silicate glass ceramic according to the invention. All those embodiments which are given as preferred for the glass ceramic according to the invention are also preferred for the starting glass.

In the process according to the invention, the glass with nuclei is usually prepared by means of a heat treatment of the starting glass at a temperature of in particular from 480 to 560° C. The lithium disilicate glass ceramic according to the invention is then preferably produced from the glass with nuclei through further heat treatment at usually 600 to 750 and in particular 650 to 750° C.

Thus, much lower temperatures are used according to the invention for the crystallization of lithium disilicate than with the conventional lithium disilicate glass ceramics. The energy thus saved represents a clear advantage. Surprisingly, this low crystallization temperature is also possible in the absence of components, such as K_2O and Al_2O_3 as well as BaO, regarded as essential for conventional glass ceramics.

To prepare the starting glass, the procedure is in particular that a mixture of suitable starting materials, such as carbonates, oxides, phosphates and fluorides, is melted at temperatures of in particular from 1300 to 1600° C. for 2 to 10 h. To achieve a particularly high homogeneity, the obtained glass melt is poured into water in order to form a granular glass material, and the obtained granular material is then melted again.

The melt can then be poured into moulds to produce blanks of the starting glass, so-called solid glass blanks or monolithic blanks.

It is also possible to put the melt into water again in order to prepare a granular material. This granular material can then be pressed, after grinding and optionally addition of further components, such as colourants and fluorescent agents, to form a blank, a so-called powder green compact.

Finally, the starting glass can also be processed to form a powder after granulation.

The starting glass, e.g. in the form of a solid glass blank, a powder green compact or in the form of a powder, is then subjected to at least one heat treatment in the range of from 450 to 950° C. It is preferred that a first heat treatment is initially carried out at a temperature in the range of from 480 to 560° C. to prepare a glass according to the invention with nuclei which are suitable for forming lithium metasilicate and/or lithium disilicate crystals. This first heat treatment is preferably carried out for a period of from 10 min to 120 min and in particular 10 min to 30 min. The glass with nuclei can then preferably be subjected to at least one further temperature treatment at a higher temperature and in particular more than 570° C. to effect crystallization of lithium metasilicate or lithium disilicate. This further heat treatment is preferably carried out for a period of from 10 min to 120 min, in particular 10 min to 60 min and particularly preferred 10 min to 30 min. To crystallize lithium disilicate, the further heat treatment is usually carried out at 600 to 750, preferably 650 to 750 and particularly preferred 700 to 750° C.

Therefore, in a preferred embodiment of the process

(a) the starting glass is subjected to a heat treatment at a temperature of from 480 to 560° C. in order to form the glass with nuclei, and

(b) the glass with nuclei is subjected to a heat treatment at a temperature of from 700 to 750° C. in order to form the glass ceramic with lithium disilicate as main crystal phase.

The duration of the heat treatments carried out in (a) and (b) is preferably as given above.

The at least one heat treatment carried out in the process according to the invention can also take place during a hot pressing or sintering-on of the glass according to the invention or the glass ceramic according to the invention.

Dental restorations, such as bridges, inlays, onlays, crowns, veneers, facets or abutments, can be prepared from the glass ceramics according to the invention and the glasses according to the invention. The invention therefore also relates to their use for the preparation of dental restorations. It is preferred that the glass ceramic or the glass is shaped into the desired dental restoration by pressing or machining.

The pressing is usually carried out at increased pressure and increased temperature. It is preferred that the pressing is carried out at a temperature of from 700 to 1200° C. It is further preferred to carry out the pressing at a pressure of from 2 to 10 bar. During pressing, the desired shape change is achieved by viscous flow of the material used. The starting glass according to the invention and in particular the glass with nuclei according to the invention, the lithium metasilicate glass ceramic according to the invention and the lithium disilicate glass ceramic according to the invention can be used for the pressing. The glasses and glass ceramics according to the invention can be used in particular in the form of blanks, e.g. solid blanks or powder green compacts, e.g. in unsintered, partly sintered or densely-sintered form.

The machining is usually carried out by material removing processes and in particular by milling and/or grinding. It is particularly preferred that the machining is carried out as part of a CAD/CAM process. The starting glass according to the invention, the glass with nuclei according to the invention, the lithium metasilicate glass ceramic according to the invention and the lithium disilicate glass ceramic according to the invention can be used for the machining. The glasses and glass ceramics according to the invention can be used in particular in the form of blanks, e.g. solid blanks or powder green compacts, e.g. in unsintered, partly sintered or densely-sintered form. The lithium metasilicate glass ceramic according to the invention and lithium disilicate glass ceramic according to the invention are preferably used for the machining. The lithium disilicate glass ceramic can also be used in a not yet fully crystallized form which was produced by heat treatment at a lower temperature. This has the advantage that an easier machining, and thus the use of simpler equipment for the machining, is possible. After the machining of such a partly crystallized material, the latter is usually subjected to a heat treatment at a higher temperature and in particular 650 to 750° C. and preferably about 700° C. in order to effect further crystallization of lithium disilicate.

In general, after the preparation of the dental restoration shaped as desired by pressing or machining, the latter can also in particular be heat-treated in order to convert precursors used, such as starting glass, glass with nuclei or lithium metasilicate glass ceramic, into lithium disilicate glass ceramic or to increase the crystallization of lithium disilicate or to reduce the porosity, e.g. of a porous powder green compact used.

However, the glass ceramic according to the invention and the glass according to the invention are also suitable as coating material of e.g. ceramics and glass ceramics. The invention is therefore also directed to the use of the glass according to the invention or the glass ceramic according to the invention for coating of in particular ceramics and glass ceramics.

The invention also relates to a process for coating ceramics and glass ceramics, in which the glass ceramic according to the invention or the glass according to the invention is applied to the ceramic or glass ceramic and is subjected to increased temperature.

This can take place in particular by sintering-on and preferably by pressing-on. With sintering-on, the glass ceramic or the glass is applied to the material to be coated, such as ceramic or glass ceramic, in the usual way, e.g. as powder, and then sintered at increased temperature. With the preferred pressing-on, the glass ceramic according to the invention or the glass according to the invention is pressed on, e.g. in the form of powder green compacts or monolithic blanks, at an increased temperature of e.g. from 700 to 1200° C., and by applying pressure, e.g. 2 to 10 bar. The methods described in EP 231 773 and the press furnace disclosed therein can be used in particular for this. A suitable furnace is e.g. the Programat EP 5000 from Ivoclar Vivadent AG, Liechtenstein.

It is preferred that, after conclusion of the coating process, the glass ceramic according to the invention is present with lithium disilicate as main crystal phase, as it has particularly good properties.

Because of the above-described properties of the glass ceramic according to the invention and the glass according to the invention as its precursor, these are suitable in particular for use in dentistry. A subject of the invention is therefore also the use of the glass ceramic according to the invention or the glass according to the invention as a dental material and in particular for the preparation of dental restorations or as a coating material for dental restorations, such as crowns, bridges and abutments.

Finally, the glasses and glass ceramics according to the invention can also be mixed together with other glasses and glass ceramics in order to produce dental materials with properties adjusted as desired. Compositions and in particular dental materials which comprise the glass according to the invention or the glass ceramic according to the invention in combination with at least one other glass and/or one other glass ceramic therefore represent a further subject of the invention. The glass according to the invention or the glass ceramic according to the invention can therefore be used in particular as main component of an inorganic-inorganic composite or in combination with a plurality of other glasses and/or glass ceramics, wherein the composites or combinations can be used in particular as dental materials. The combinations or composites can particularly preferably be present in the form of sintered blanks. Examples of other glasses and glass ceramics for the preparation of inorganic-inorganic composites and of combinations are disclosed in DE 43 14 817, DE 44 23 793, DE 44 23 794, DE 44 28 839, DE 196 47 739, DE 197 25 553, DE 197 25 555, DE 100 31 431 and DE 10 2007 011 337. These glasses and glass ceramics belong to the group of silicates, borates, phosphates or aluminosilicates. Preferred glasses and glass ceramics are of SiO_2—Al_2O_3—K_2O type (with cubic or tetragonal leucite crystals), SiO_2—B_2O_3—Na_2O type, alkali-silicate type, alkali-zinc-silicate type, silicophosphate type, SiO_2—ZrO_2 type and/or lithium-aluminosilicate type (with spodumene crystals). By mixing such glasses or glass ceramics with the glasses and/or glass ceramics according to the invention, for example the coefficient of thermal expansion can be adjusted as desired in a broad range of from 6 to $20 \cdot 10^{-6}$ K^{-1}.

The invention is explained in more detail below by means of examples.

EXAMPLES

Examples 1 to 16

Composition and Crystal Phases

A total of 16 glasses and glass ceramics according to the invention with the composition given in Table I were prepared by melting corresponding starting glasses followed by heat treatment for controlled nucleation and crystallization.

For this, the starting glasses weighing from 100 to 200 g were first melted from customary raw materials at 1400 to 1500° C., wherein the melting was very easily possible without formation of bubbles or streaks. By pouring the starting glasses into water, glass frits were prepared which were then melted a second time at 1450 to 1550° C. for 1 to 3 h for homogenization.

In the case of Examples 1 to 9 and 11 to 16, the obtained glass melts were then poured into preheated moulds in order to produce glass monoliths. All glass monoliths proved transparent.

In the case of Example 10, the obtained glass melt was cooled to 1400° C. and converted to a fine-particle granular material by pouring into water. The granular material was dried and ground to a powder with a particle size of <90 μm. This powder was moistened with some water and pressed to form a powder green compact at a pressing pressure of 20 MPa.

The glass monoliths (Examples 1-9 and 11-16) as well as the powder green compact (Example 10) were then converted by thermal treatment to glasses and glass ceramics according to the invention. The thermal treatments used for controlled nucleation and controlled crystallization are also given in Table I. The following meanings apply

T_N and t_N temperature and time used for nucleation

T_c and t_c temperature and time used for crystallization of lithium disilicate or lithium metasilicate

It can be seen that a first heat treatment in the range of from 480 to 510° C. resulted in the formation of lithium silicate glasses with nuclei and these glasses crystallized in the case of Examples 1-10 and 12 due to a further heat treatment already at 700 to 750° C. and in particular 700° C. to glass ceramics with lithium disilicate as main crystal phase, as was established by X-ray diffraction tests. The heat treatment at a temperature of only 660 to 680° C. resulted in the case of Examples 11 and 13-16 in the formation of glass ceramics with lithium metasilicate as main crystal phase.

The produced lithium disilicate glass ceramics had high fracture toughness values, measured as critical stress intensity factor K_{IC}, of more than 2.0 $MPa \cdot m^{0.5}$.

The biaxial strength σ_B was also high, at at least 480 MPa. It was determined according to dental standard ISO 6872 (2008) on test pieces that were prepared by machining of the respective lithium disilicate glass ceramic. A CEREC-InLab machine (Sirona, Bensheim) was used for the machining.

The produced lithium disilicate glass ceramics and lithium metasilicate glass ceramics were able to be very satisfactorily machined into the form of various dental restorations in a CAD/CAM process or by hot pressing, which restorations were also provided with a veneer if required.

They were also able to be applied by hot pressing as coatings onto in particular dental restorations, e.g. in order to veneer the latter as desired.

Example 17

Hot Pressing of Glass with Nuclei

A glass with the composition according to Examples 6 and 7 was prepared by mixing corresponding raw materials in the form of oxides and carbonates for 30 min in a Turbula mixer and then melting the mixture at 1450° C. for 120 min in a platinum crucible. The melt was poured into water in order to obtain a fine-particle granular glass material. This granular glass material was melted again at 1530° C. for 150 min in order to obtain a glass melt with particularly high homogeneity. The temperature was reduced to 1500° C. for 30 min and cylindrical glass blanks with a diameter of 12.5 mm were then poured into pre-heated, separable steel moulds or graphite moulds. The obtained glass cylinders were then nucleated in the range of from 480-560° C., depending on the composition, and stress-relieved.

The nucleated glass cylinders were then processed by hot pressing at a pressing temperature of from 900-1100° C. using an EP600 press furnace, Ivoclar Vivadent AG, to form dental restorations, such as inlays, onlays, veneers, partial crowns, crowns, laminating materials and laminates. In each case, lithium disilicate was detected as main crystal phase.

TABLE I

	Example					
Composition	1 wt.-%	2 wt.-%	3 wt.-%	4 wt.-%	5 wt.-%	6 wt.-%
SiO_2	73.8	75.0	73.8	72.8	73.8	73.8
Li_2O	15.3	15.5	15.3	15.1	15.3	15.3
P_2O_5	3.4	3.4	3.4	2.9	3.4	3.4
Al_2O_3	3.0	3.0	3.0	3.2	—	—
Rb_2O	4.5	3.1	—	6.0	4.5	—
Cs_2O	—	—	4.5	—	—	4.5
Y_2O_3	—	—	—	—	3.0	3.0
TiO_2	—	—	—	—	—	—
MgO	—	—	—	—	—	—
Ag_2O						
Optical properties (after pouring)	transparent	transparent	transparent	transparent	transparent	transparent
T_g/° C.	467	475	470	469	479	481
T_N/° C.	480	480	480	500	500	500
t_N/min.	10	10	10	10	10	10
T_c/° C.	700	700	700	700	700	700
t_c/min.	20	20	20	20	20	20
Main crystal phase	lithium di-silicate	lithium di-silicate	lithium di-silicate	lithium di-silicate	lithium di-silicate	lithium di-silicate
Other crystal phases	Li_2SiO_3	Li_3PO_4	Li_2SiO_3	quartz, Li_2SiO_3	Li_3PO_4	Li_3PO_4
K_{IC}/ MPa · $m^{1/2}$	2.29	2.31	2.08	2.67	2.38	2.45
σ_B/MPa	610	—	—	—	—	480

	Example					
Composition	7 wt.-%	8 wt.-%	9 wt.-%	10 wt.-%	11 wt.-%	12 wt.-%
SiO_2	73.8	73.8	75.3	76.6	62.1	76.4
Li_2O	15.3	15.3	15.7	15.9	12.9	15.9
P_2O_5	3.4	3.4	3.4	—	7.0	3.5
Al_2O_3	—	—	3.5	3.0	3.0	—
Rb_2O	—	2.0	2.0	4.5	7.5	4.2
Cs_2O	4.5	—	—	—	7.5	—
Y_2O_3	—	3.0	—	—	—	—
TiO_2	3.0	—	—	—	—	—
MgO	—	2.5	—	—	—	—
Ag_2O			0.1	—	—	—
Optical properties (after pouring)	transparent	transparent	transparent	transparent	slightly opalescent	transparent
T_g/° C.	479	471	471	471	488	475
T_N/° C.	500	500	490	490	510	500
t_N/min.	10	10	10	10	10	10
T_c/° C.	700	700	700	750	680	740

TABLE I-continued

t_c/min.	20	20	20	30	20	20
Main crystal phase	lithium di-silicate	lithium di-silicate	lithium di-silicate	lithium di-silicate	lithium meta-silicate	lithium di-silicate
Other crystal phases	Li_3PO_4	Li_3PO_4	Li_2SiO_3	lithium meta-silicate	—	Li_3PO_4, cristo-balite
K_{IC}/ $MPa \cdot m^{1/2}$	2.56	2.36	—	—	—	—
σ_B/MPa	—	—	—	—	—	—

	Example			
Composition	13 wt.-%	14 wt.-%	15 wt.-%	16 wt.-%
SiO_2	70.1	72.8	70.1	70.2
Li_2O	14.5	15.1	19.0	14.5
P_2O_5	3.2	4.0	3.4	3.2
Al_2O_3	2.9	3.0	3.0	2.8
Rb_2O	4.3	5.1	4.5	—
Cs_2O	—	—	—	4.3
Y_2O_3	—	—	—	—
TiO_2	—	—	—	—
MgO	—	—	—	—
Ag_2O	—	—	—	—
ZrO2	5.0	—	—	5.0
Optical properties (after pouring)	transparent	transparent	transparent	transparent
T_g/° C.	484	469	455	493
T_N/° C.	500	500	500	500
t_N/min.	10	10	10	10
T_c/° C.	660	680	660	660
t_c/min.	20	20	20	20
Main crystal $phase_{RT-XRD}$	lithium meta-silicate	lithium meta-silicate	lithium meta-silicate	lithium meta-silicate
Other crystal phases	—	—	lithium di-silicate	lithium di-silicate

The invention claimed is:

1. Lithium silicate glass ceramic which comprises a monovalent metal oxide selected from Rb_2O, Cs_2O and mixtures thereof and has lithium metasilicate as a main crystal phase.

2. Glass ceramic according to claim **1**, wherein lithium silicate glass ceramic is excluded which comprises at least 6.1 wt.-% ZrO_2.

3. Glass ceramic according to claim **1**, wherein lithium silicate glass ceramic is excluded which comprises at least 8.5 wt.-% transition metal oxide selected from the group consisting of oxides of yttrium, oxides of transition metals with an atomic number from 41 to 79 and mixtures of these oxides.

4. Glass ceramic according to claim **1**, which comprises less than 1.0 wt.-% K_2O.

5. Glass ceramic according to claim **1**, which comprises less than 5.3 wt.-% Al_2O_3 or in which the molar ratio of monovalent metal oxide to Al_2O_3 is at least 0.5.

6. Glass ceramic according to claim **1**, which comprises less than 3.8 wt.-% BaO.

7. Glass ceramic according to claims **1**, which comprises the monovalent metal oxide or mixtures thereof in an amount of from 0.1 to 17.0 wt.-%.

8. Glass ceramic according to claim **1**, which has lithium disilicate as a main crystal phase.

9. Glass ceramic according to claim **1**, which comprises 55.0 to 85.0 wt.-% SiO_2.

10. Glass ceramic according to claim **1**, which comprises 9.0 to 20.0 wt.-% Li_2O.

11. Glass ceramic according to claim **1**, which comprises 0 to 12.0 wt.-% P_2O_5.

12. Glass ceramic according to claim **1**, which comprises K_2O, Na_2O and mixtures thereof in an amount of less than 1.0 wt.-%.

13. Glass ceramic according to claim **1**, which comprises at least one and preferably all of the following components:

Component	wt.-%
SiO_2	55.0 to 85.0
Li_2O	9.0 to 17.0
Rb_2O and/or Cs_2O	0.1 to 15.0
P_2O_5	0 to 12.0.

14. Glass ceramic according to claim **1**, which has lithium disilicate as a main crystal phase and a fracture toughness, measured as K_{IC} value, of at least about 2.0 $MPa \cdot m^{0.5}$ 5.

15. Glass ceramic according to claim **1**, wherein the molar ratio between SiO_2 and Li_2O is from 2.2 to 2.6.

16. Glass ceramic according to claim **1** wherein the glass ceramic is present in the form of a powder, a granular material, a blank or a dental restoration.

17. Glass ceramic according to claim **1**, which has lithium metasilicate as a main crystal phase and more than 5 vol.-% lithium metasilicate crystals.

18. Glass ceramic according to claim **1**, which has lithium metasilicate as a main crystal phase and more than 10 vol.-% lithium metasilicate crystals.

19. Glass ceramic according to claim **1**, which has lithium metasilicate as a main crystal phase and more than 20 vol.-% lithium metasilicate crystals.

20. Glass ceramic according to claims **1**, which has lithium disilicate as a main crystal phase and more than 10 vol.-%, lithium disilicate crystals.

21. Glass ceramic according to claims **1**, which has lithium disilicate as a main crystal phase and more than 20 vol.-%, lithium disilicate crystals.

22. Glass ceramic according to claims **1**, which has lithium disilicate as a main crystal phase and more than 30 vol.-%, lithium disilicate crystals.

23. Process for the preparation of the glass ceramic according to claim **1**, wherein a starting glass or a glass with nuclei is subjected to at least one heat treatment in the range of from 450 to 950° C.

24. Process for the preparation of a lithium silicate glass ceramic which comprises a monovalent metal oxide selected from Rb_2O, Cs_2O and mixtures thereof, wherein

(a) a starting glass is subjected to a heat treatment at a temperature of from 480 to 560° C. in order to form a glass with nuclei, and

(b) the glass with nuclei is subjected to a heat treatment at a temperature of from 700 to 750° C. in order to form the glass ceramic with lithium disilicate as main crystal phase.

25. Process of using the glass ceramic according to claim **1** as a dental material.

26. Process according to claim **25**, wherein the glass ceramic is shaped by pressing or machining to a dental restoration.

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